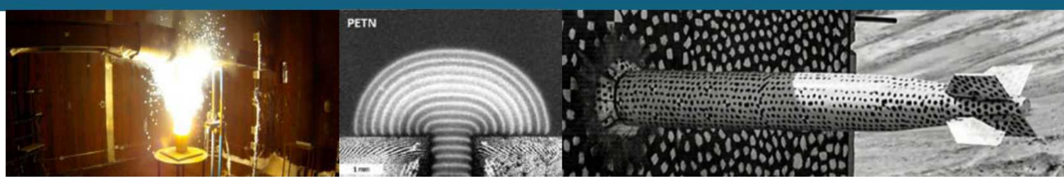
Sandia National Laboratories

SAND2019-6839C

High-Throughput Initiation: Flyer and Thin-Film Explosive Characterization



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21st Biennial Conference of the APS Topical Group on Shock Compression of Condensed Matter, Portland, OR, June 16 – 21, 2019.

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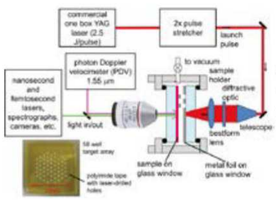
Introduction and motivation

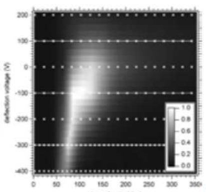
Explosive testing is expensive and time-consuming

High-throughput methods are available

Laser-driven shock experiments allow for robotic positioning on optical axis



Dlott (2017).



Fossum (2012).

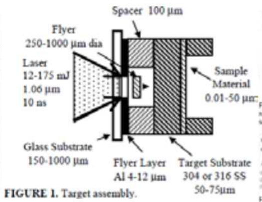
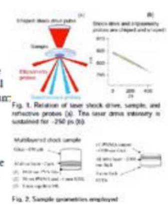
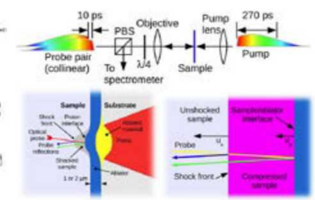


FIGURE 1. Target assembly.

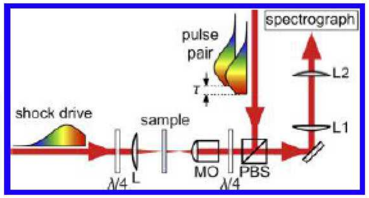
Buelow (2004).



McGrane (2010).



Armstrong (2013).



Park (2018).

Dlott, D. D., **Shock compression dynamics under a microscope**, AIP Conference Proceedings, (2017).

Fossum, E. C., Molek, C. D., Lewis, W. K., and Fajardo, M. E., **Benchtop Energetics: Hyperthermal Species Detection**, Propellants, Explosives, Pyrotechnics, (2012).

Buelow, S. J., Anderson, J. E., Aiken, A. C., Arrington, C. A., and Jones, B., **Mass Spectral Studies of Shocked Salts and Nitrocellulose Polymer Films**, AIP Conference Proceedings, vol. 706, no. 1, pp. 1377-1380, (2004).

McGrane, S. D., Dang, N. C., Whitley, V. H., Bolme, C. A., and Moore, D. S., **Transient absorption spectroscopy of laser shocked explosives**, 14th International Detonation Symposium, Coeur d'Alene, ID, (April 11-16, 2010).

Armstrong, M. R., Zaug, J. M., Goldman, N., Kuo, I. F. W., Crowhurst, J. C., Howard, W. M., Carter, J. A., Kashgarian, M., Chesser, J. M., Barbee, T. W., and Bastea, S., **Ultrafast Shock Initiation of Exothermic Chemistry in Hydrogen Peroxide**, The Journal of Physical Chemistry A, vol. 117, no. 49, pp. 13051-13058, (2013).

Park, S. D., Armstrong, M. R., Kohl, I. T., Zaug, J. M., Knepper, R., Tappan, A. S., Bastea, S., and Kay, J. J., **Ultrafast Shock-Induced Reactions in Pentaerythritol Tetranitrate Thin Films**, The Journal of Physical Chemistry A, vol. 122, no. 41, pp. 8101-8106, (2018).

Beppler, C. L., Hotchkiss, P. J., and Tappan, A. S., **Combinatorial, Microscale Fuel/Oxidizer Formulations for the Systematic Determination of Homemade Explosives Properties**, Sandia National Laboratories Report, SAND16-0381, (January, 2016).

Laser-driven flyer

Continuum Powerlite Precision II 9000, 8.9 ns, 2.5 J, pulsed Nd:YAG

- Refurbished, M^2 increased

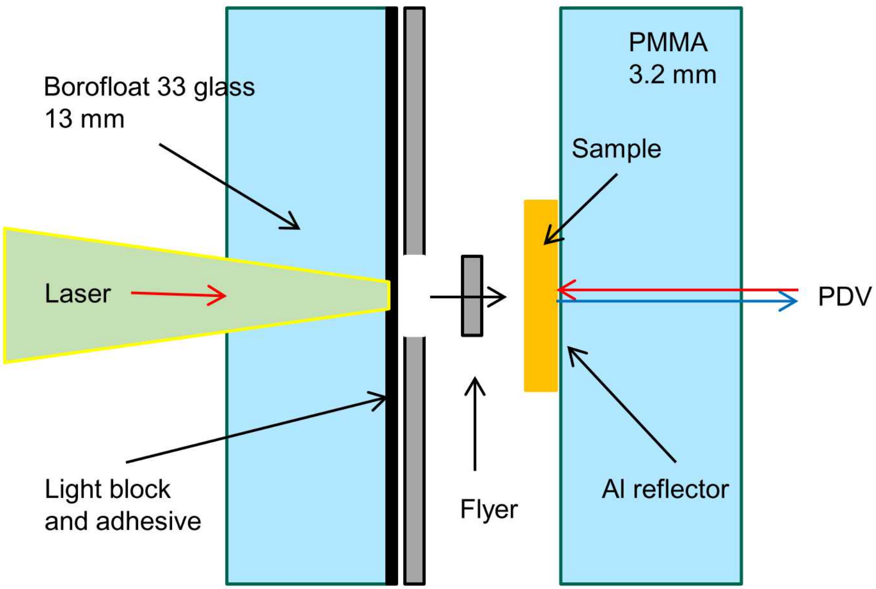
Laser driven flyer defines shock pulse width (> 25 µm) and spot size (~ 1 mm)

- Material choice defines pressure

Flyer characterization with PDV

- ~ 4000 m/s to date

Experiment configuration based on work by Dana Dlott's group (UIUC)



Cross-section cartoon of laser driven flyer used in High-Throughput Initiation experiment.

High-Throughput Initiation Experiment used to study shock initiation of explosives

Laser-based initiation and laser-based diagnostics allow for robotic positioning

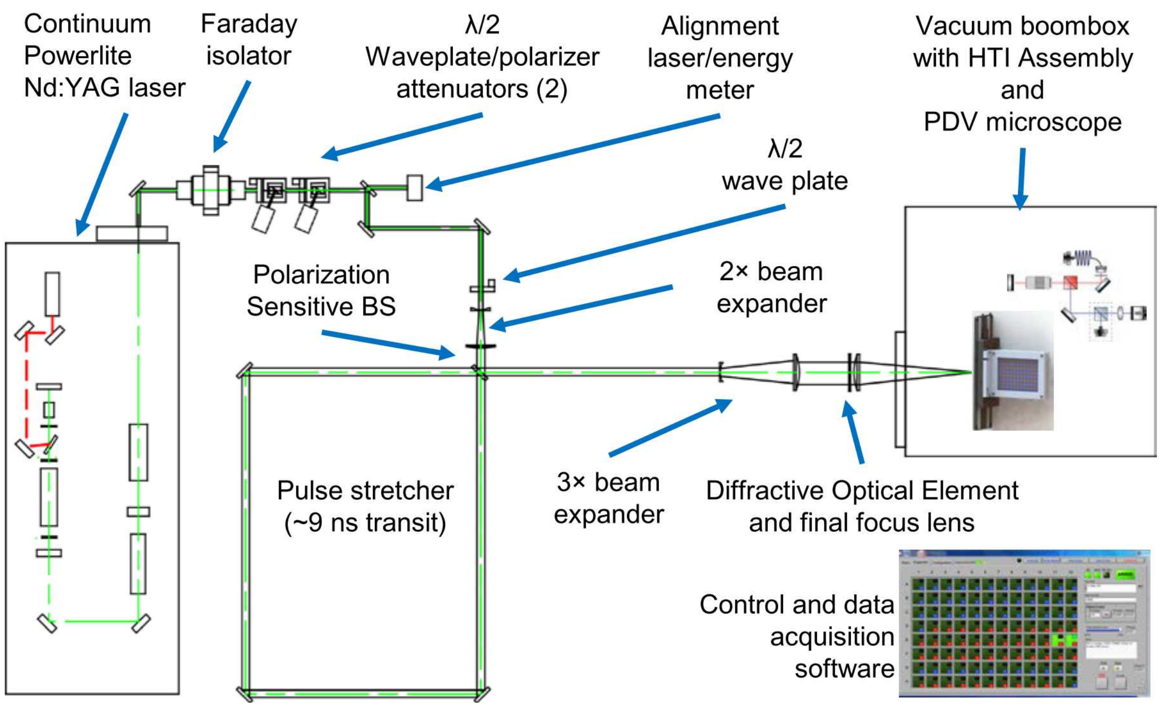
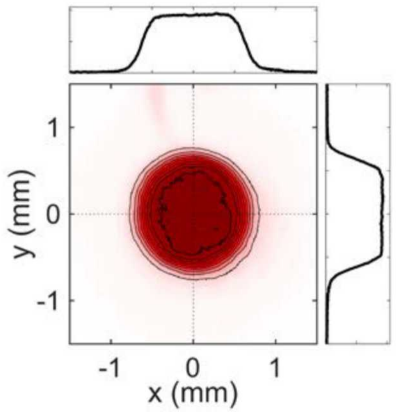


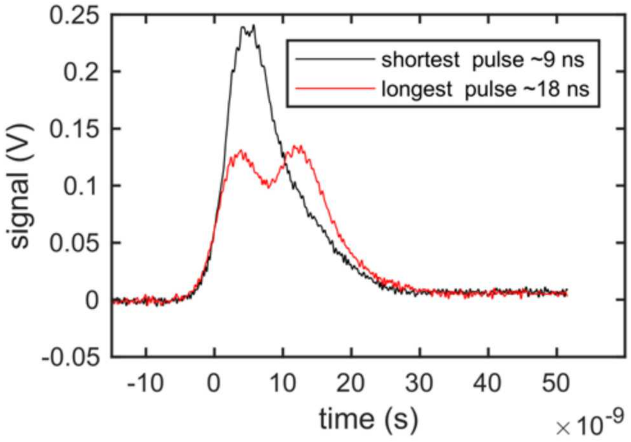
Diagram of optical system for the High-Throughput Initiation experiment.

Laser-driven flyer characterization

Launch laser beam profile (in both space and time) defines the quality of the flyer



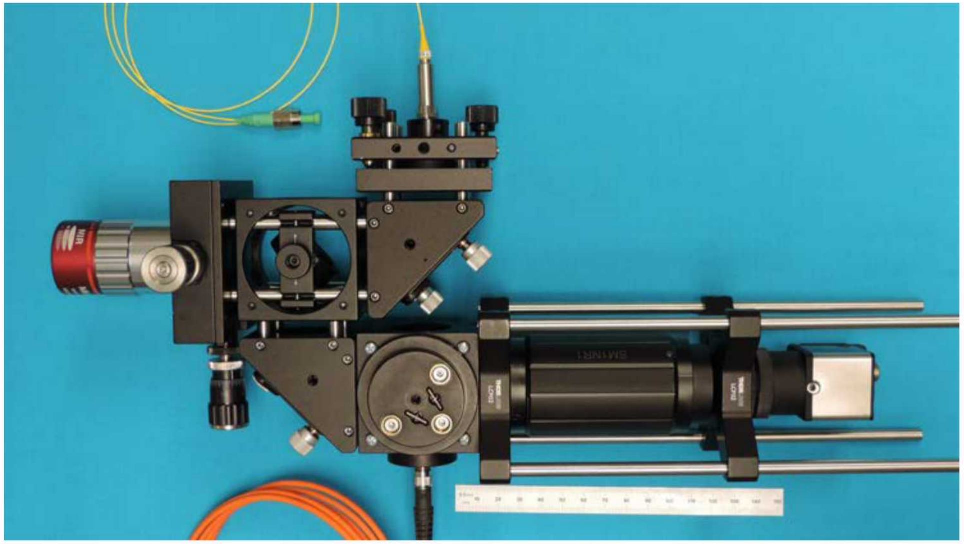
Beam profile of launch laser at flyer optic focus showing a high-quality 1.1 mm diameter top hat profile.



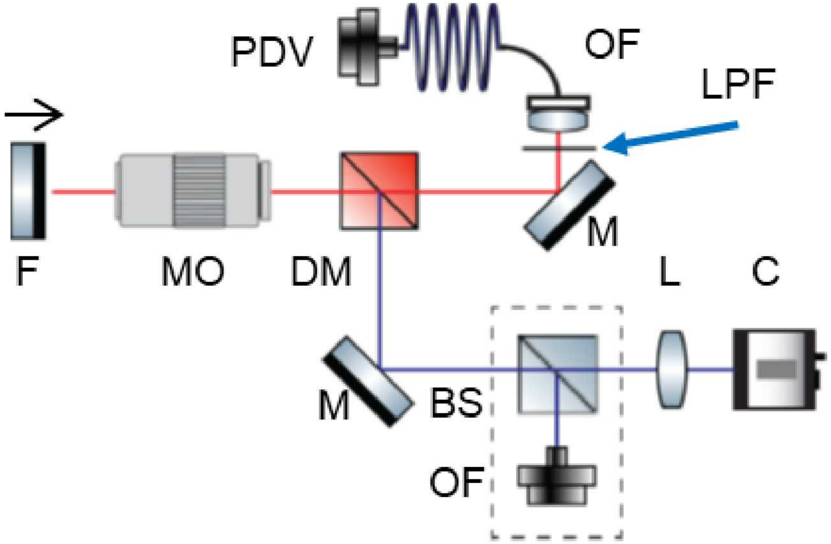
Photodiode signal showing the launch laser pulse duration at the shortest, ~9 ns duration with the pulse stretcher blocked, and the longest, ~18 ns duration with balanced reflection/transmission at the pulse stretcher.

Photonic Doppler velocimetry

The PDV microscope is the primary diagnostic for High-Throughput Initiation



Photograph of photonic Doppler velocimetry microscope used on the High-Throughput Initiation experiment.



Optical diagram of the PDV microscope: F = flyer, MO = microscope objective, DM = dichroic mirror, LPF = long pass filter, OF = optical fiber, BS = visible beam splitter, L = lens, and C = camera.

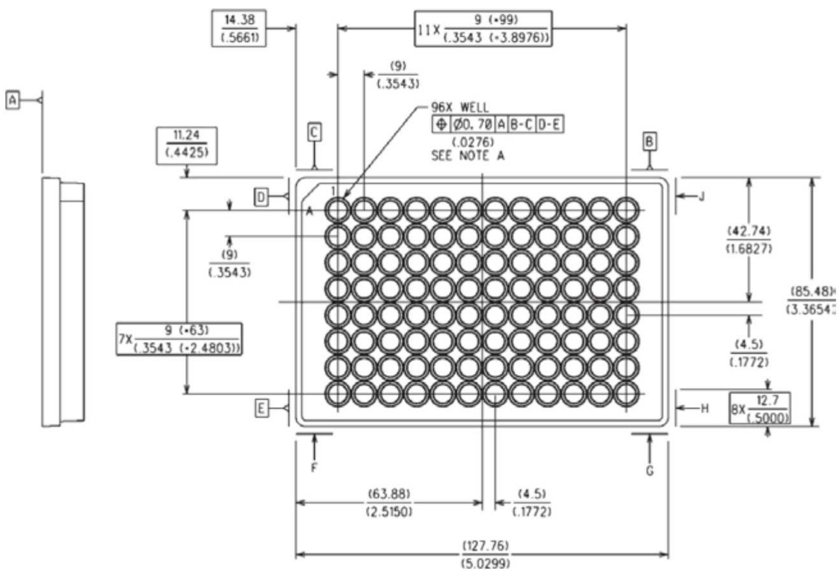
High-Throughput Initiation Experiment – Flyer Optic

Substrate: Borofloat 33 glass, 13 mm thick

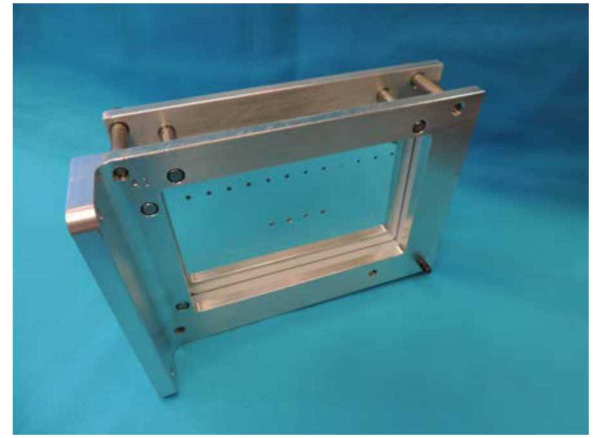
Absorber/light block: Al, 1 μm thick

Flyer: Parylene C, 26 μm thick

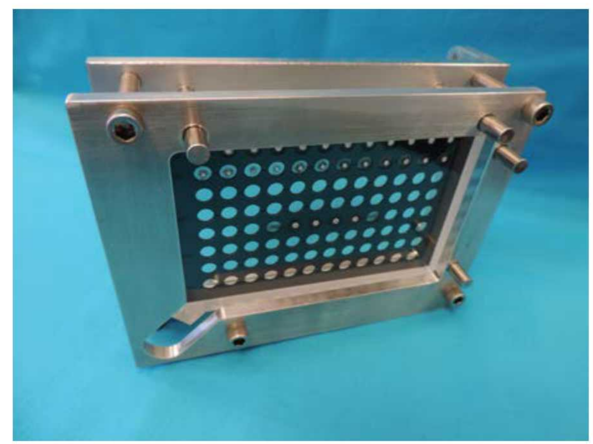
PDV reflector: Al, 50 nm



Microplate standard geometry used for High-Throughput Initiation Experiment.



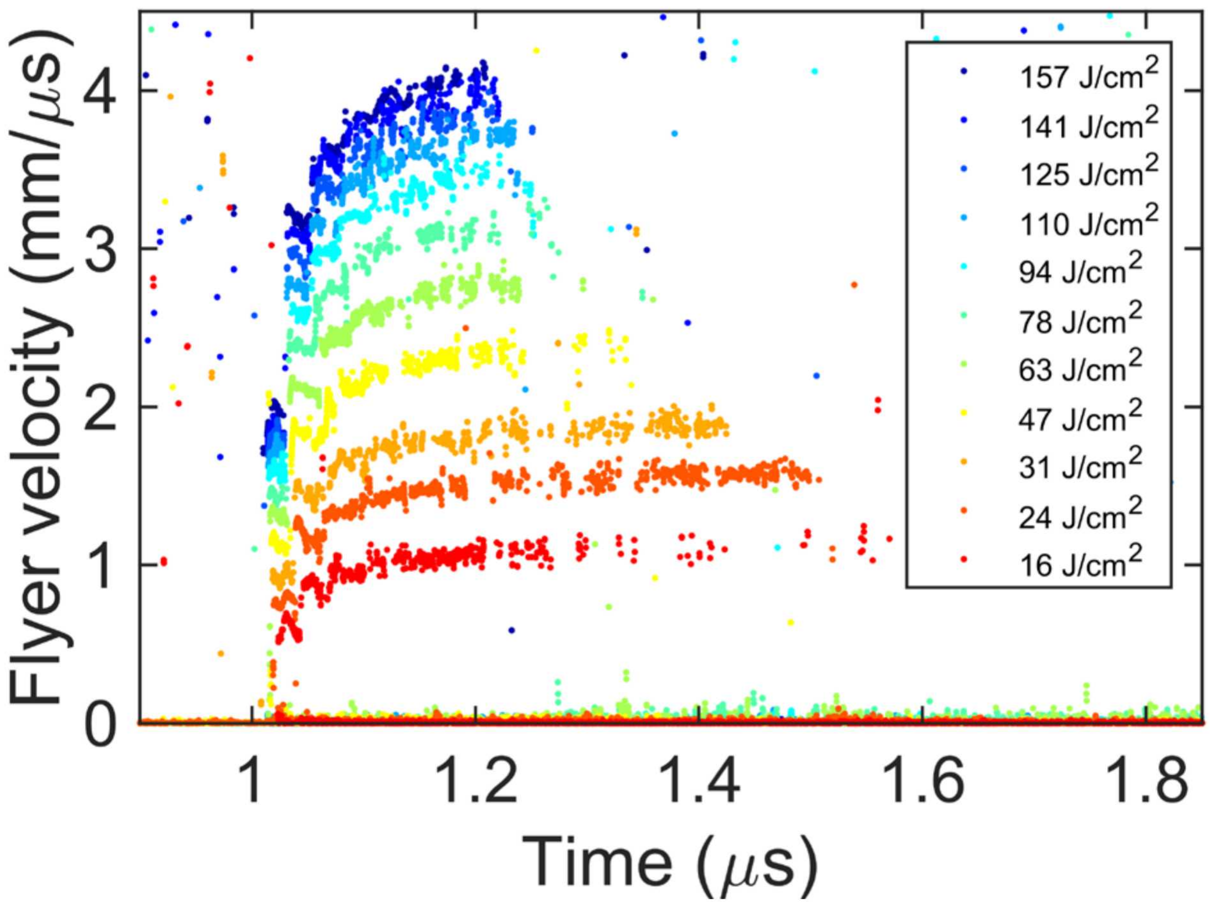
Laser entrance side of Parylene C flyer optic in HTI assembly.



Flyer side of Parylene C flyer optic in HTI assembly.

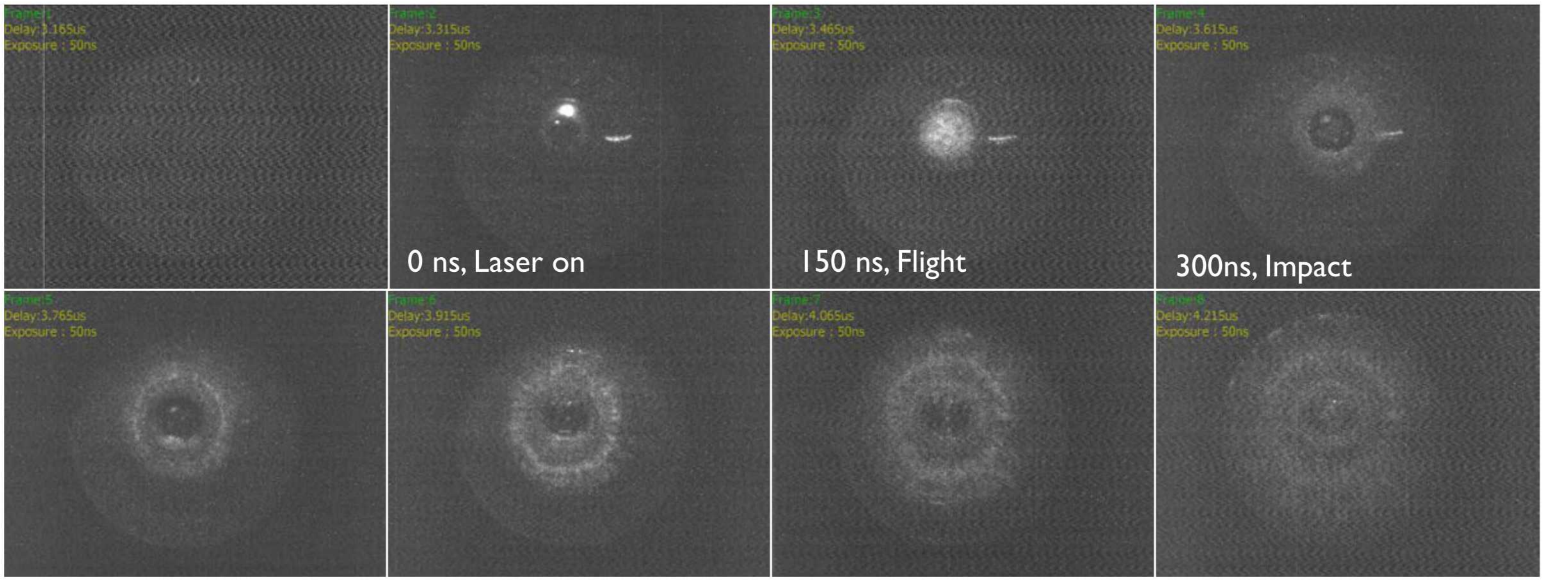
ANSI/SLAS, "1-2004: Microplates — Footprint Dimensions," 2012.

Parylene C flyer characterization shows velocities up to 4 mm/μs



Velocity (PDV) versus laser fluence for Parylene C flyers.

Parylene C flyer characterization with framing camera



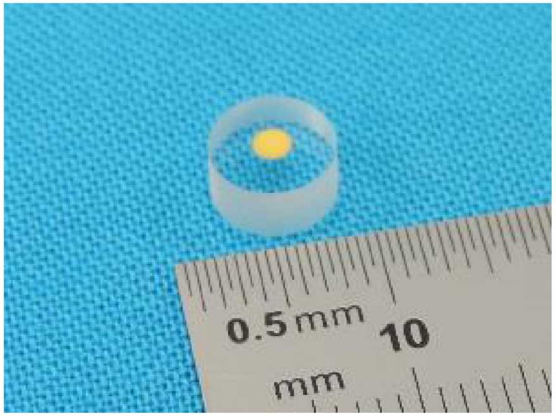
Framing camera images of Parylene C flyer launch. Images taken at 6.67 MHz (1/150 ns) with an exposure time of 50 ns. SI-LUX used for illumination with bandpass filter to reduce self-light recorded by camera. The laser can be seen in the second frame and impact occurs by the fourth.

HNS samples made by physical vapor deposition

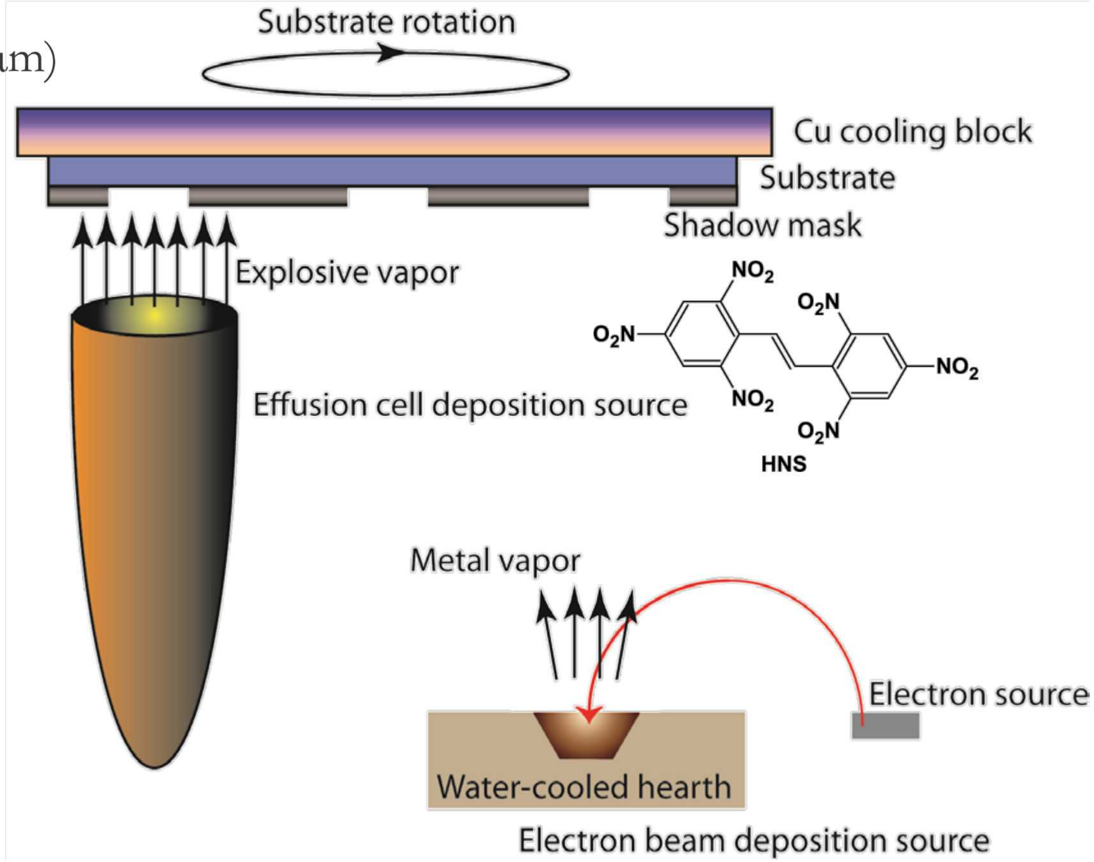
PMMA (polymethylmethacrylate) substrate

Aluminum PDV reflector (~0.25 μm)

HNS (44, 75, 119 μm)

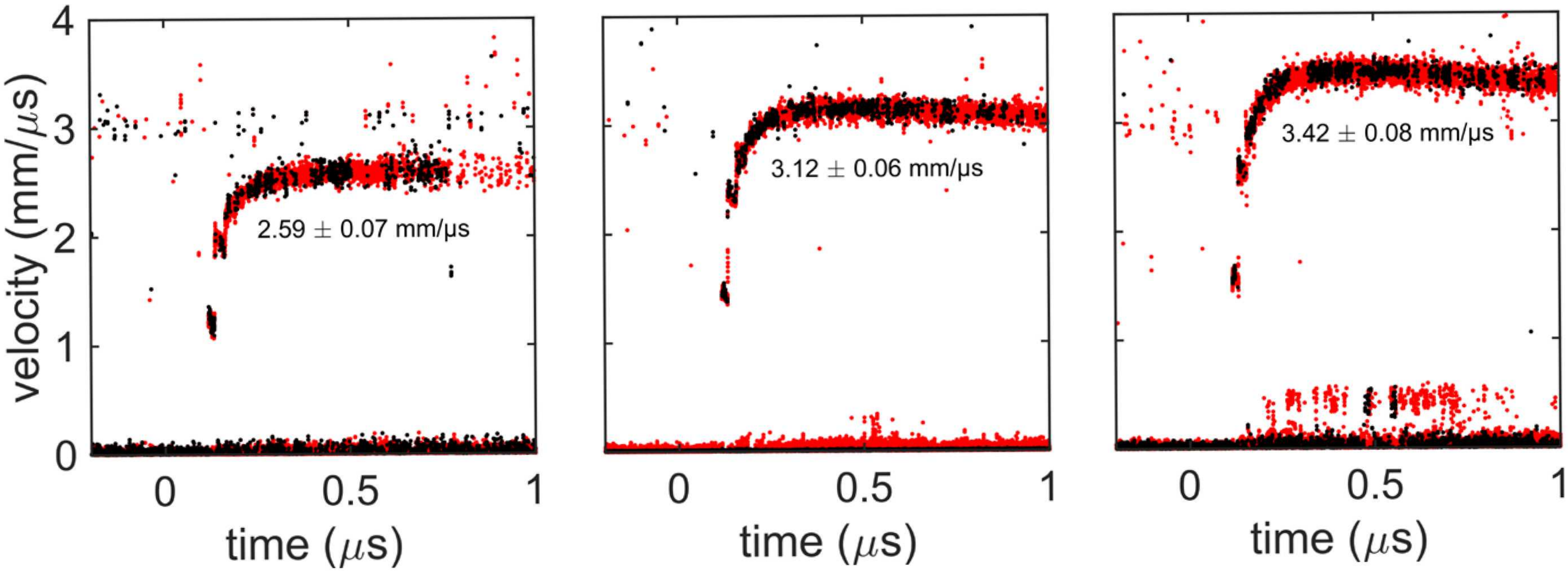


Vapor-deposited HNS sample on 6.35 mm PMMA window.



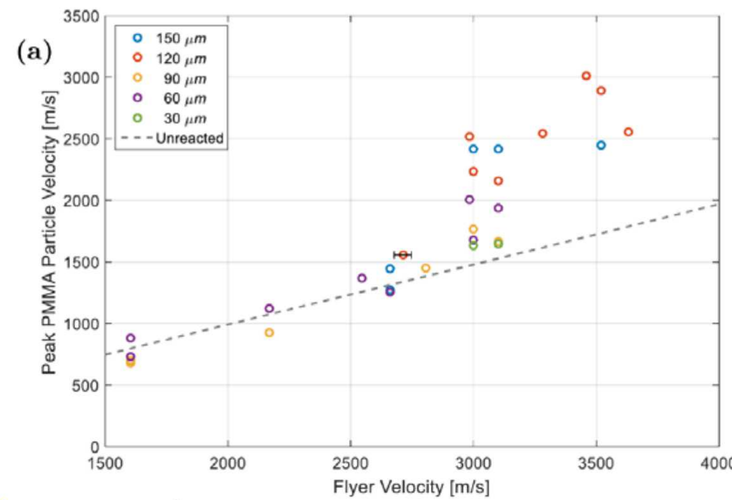
Parylene C flyers launched into HNS at three velocities

Velocity measurement made at front surface of flyer

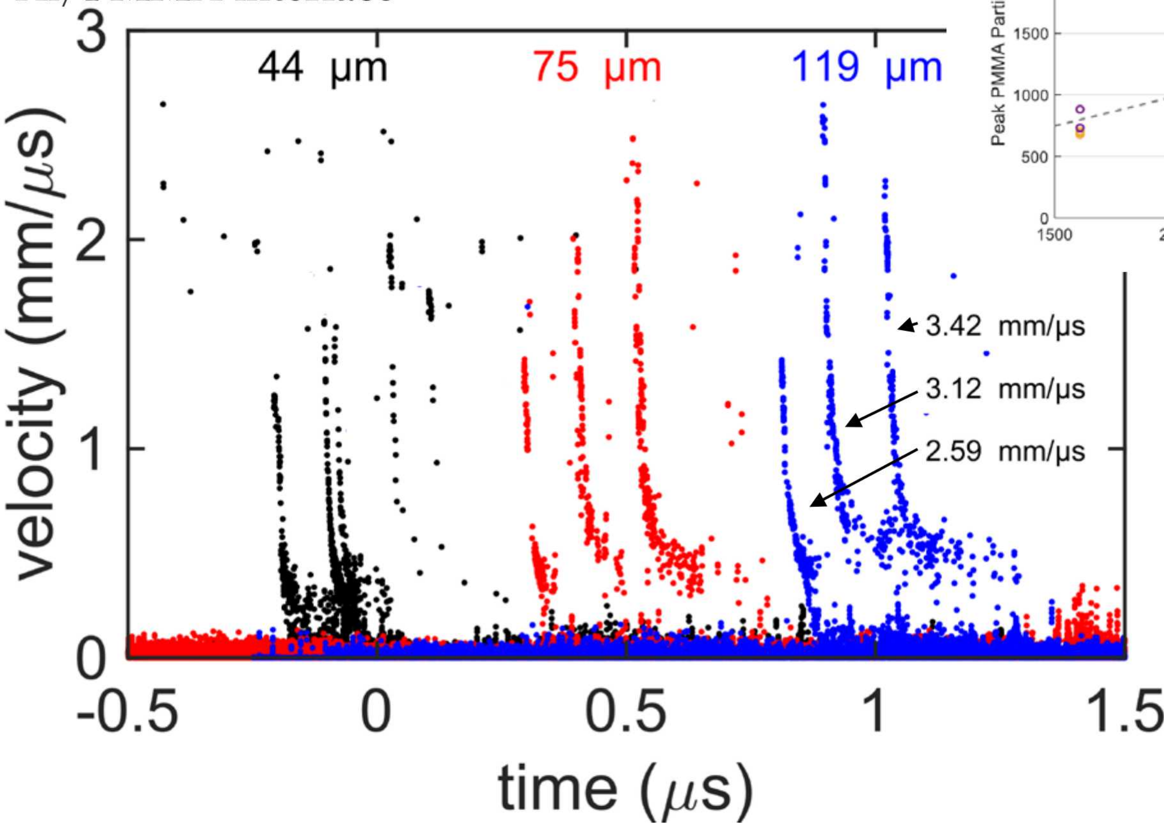


Velocity data for laser-driven Parylene C flyers launched at three fluences. Each plot has data from multiple (5 or 6) shots overlaid.

HNS appears to be building to detonation between 75 and 119 μm



Particle velocity measurement made at Al/PMMA interface



Olles showed full detonation in 120 to 150 μm of HNS at flyer velocities of ~3 mm/μs.

Graph showing compilation of HNS initiation shots at three different thicknesses, with three different impact velocities. Plots are time-shifted for clarity.

Olles JD, Wixom RR, Knepper R, Tappan AS. Observations of shock-induced chemistry with subnanosecond resolution. Applied Physics Letters. 2019;114(21):214102.

Conclusions

High-throughput initiation experiment developed based on microplate geometry

High-throughput initiation of HNS conducted with laser-driven Parylene C flyers

HNS appears to be building to detonation between 75 and 119 μm

Future work:

- Thicker aluminum PDV reflector
- Other materials

Acknowledgements

Carlos Rodriguez, Kevin Prudic, Adrian L. Casias, Amanda Nicole Dean, and Benjamin J. Hanks

- Mechanical design and fabrication

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- Sample preparation, characterization

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- Optical design/implementation

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- Technical discussions

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Leanna Minier

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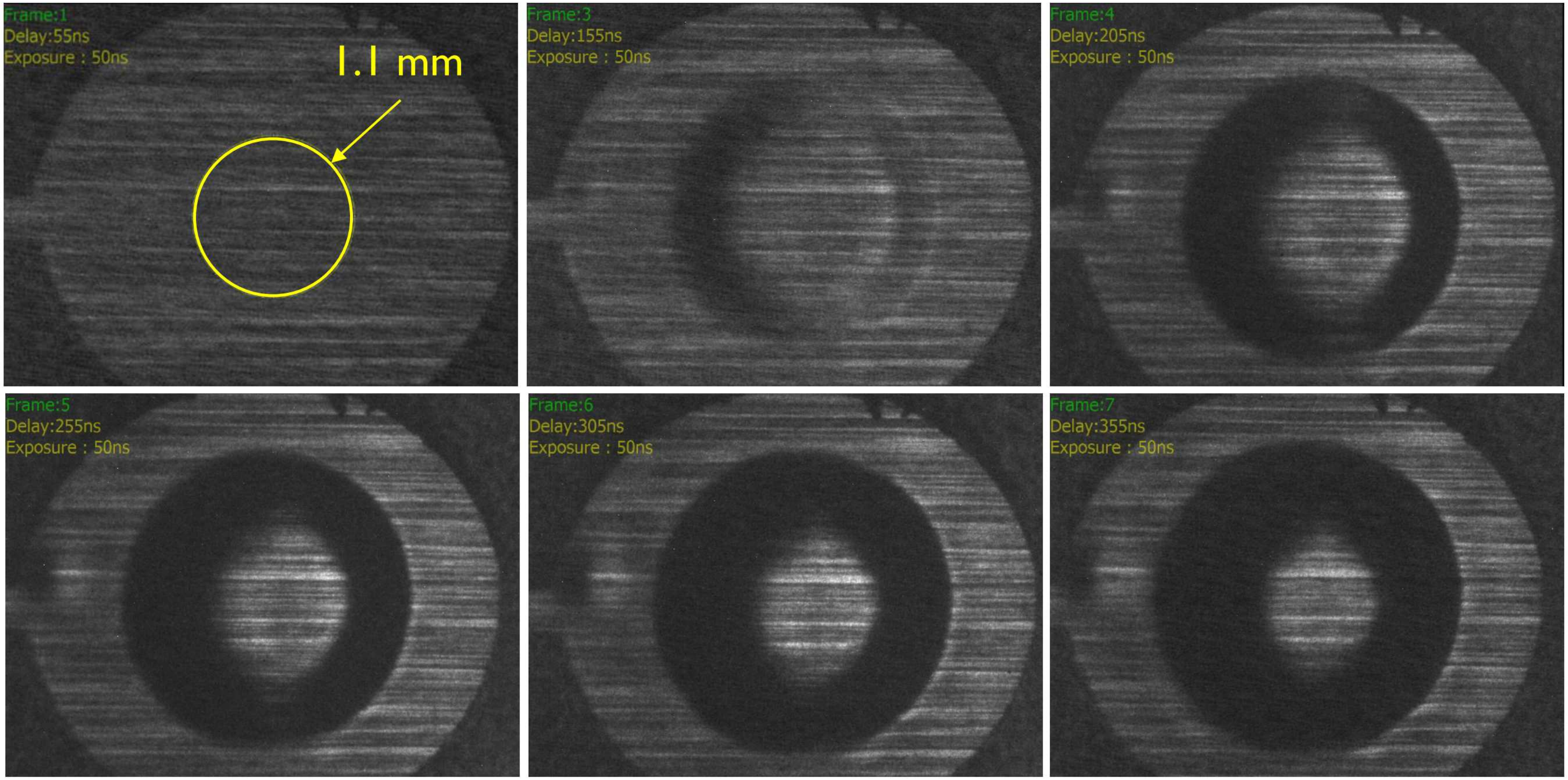
Backup slides

Framing camera images of laser-driven flyer (Aluminum)

Flyer launch appears to be planar and circular



Framing camera images of laser-driven flyer launch into the camera using a 50 ns exposure at 20 MHz (1/50 ns).

Flyer characterization (aluminum flyers)

Measurement of pulse duration (tau) as a function of Al foil thickness
- 25.4 μm, <3 ns
- 38.1 μm, 5.8 – 7.0 ns

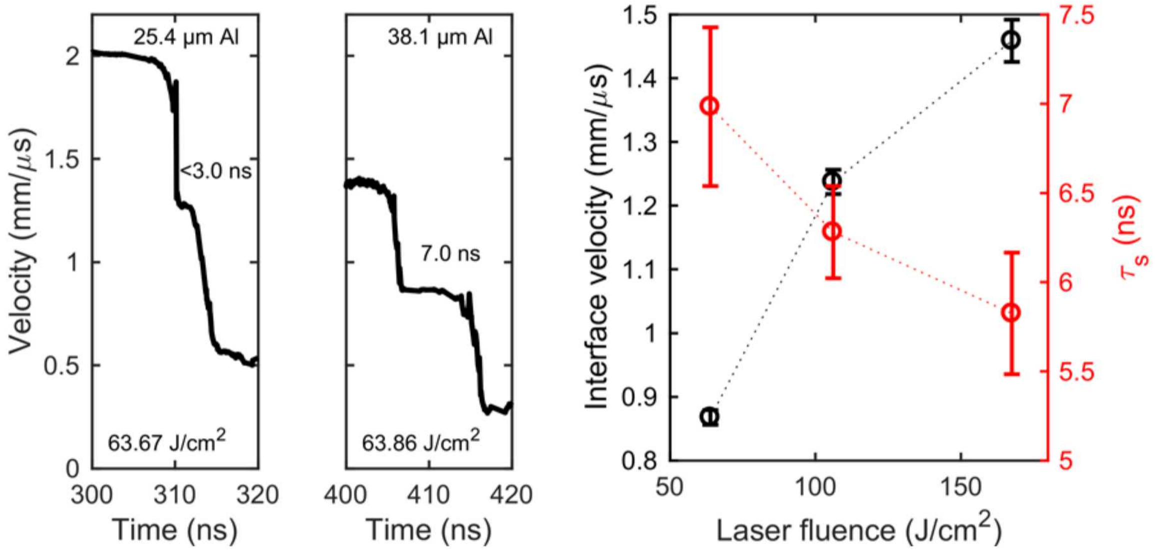
Fluence: 64 J/cm2

Particle velocity increases with fluence

Pulse width decreases with fluence

Impedance matching:

4.0, 6.6, and 8.4 GPa in PMMA



Velocity versus time data for shocks driven into PMMA by laser-driven aluminum flyers with thicknesses of 25.4 μm (<3.0 ns) and 38.1 μm (7.0 ns).
Velocity versus launch laser fluence shows increase in the flyer-PMMA interface velocity with increasing fluence, and therefore flyer velocity. The pulse duration (τ) shown on the right axis decreases with increasing fluence.

HNS sample thicknesses